# Co-variation of gonadosomatic index, condition factor and length-weight relationships of poor cod, *Trisopterus minutus* (Gadidae), in the Eastern Adriatic Sea

by

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**ABSTRACT**. - Monthly changes in length-weight relationships (LWRs), gonadosomatic index (GSI) and condition factor in the poor cod *Trisopterus minutus* (Linnaeus, 1858) were studied. A total of 1263 specimens (463 males and 800 females) ranging from 8.9 to 25.5 cm in total length (TL) were collected in the eastern Adriatic Sea. Samples were taken at monthly intervals (January-December 2007) using bottom-trawls. In total sample, the *b* values of LWRs showed that growth of both males and females was isometric. Allometric parameters of *b* values varied during the year; positive allometric growth was noted in winter (February and March), while in summer (July and August) negative allometric growth was observed. The GSI reached the highest values in February and the lowest values in September. The condition factor was low immediately after spawning (May and July) and high at the recovery phase (August). Seasonal variation of LWRs and condition factor of poor cod were connected with gonadal change as well as feeding activity and energy distribution. During summer and autumn, food energy is spent in somatic growth, while in winter it is converted in gonad development.

**RÉSUMÉ**. - Variations de l'indice gonadosomatique, du facteur de condition et des relations taille-poids du capelan, *Trisopterus minutus* (Gadidae), en mer Adriatique orientale.

Les variations saisonnières des relations taille-poids (LWRs), de l'indice gonadosomatique (GSI) et du facteur de condition du capelan (*Trisopterus minutus* L.) ont été étudiées. Au total, 1263 spécimens (463 mâles et 800 femelles) de longueur totale (TL) de 8,9 à 25,5 cm ont été récoltés en mer Adriatique orientale, mensuellement (de janvier à décembre 2007) à l'aide de chaluts de fond. Les valeurs du paramètre *b* des rapports de longueur-poids (LWRs), toutes saisons confondues, montrent que la croissance des mâles et des femelles est globalement isométrique. Le GSI a atteint des valeurs maximales en février et minimales en septembre. Le facteur de condition était bas juste après la ponte (mai et juillet) et haut pendant la phase de repos sexuel (août). Les variations saisonnières des LWRs et du facteur de condition des capelans ont été reliées au changement gonadique, aussi bien qu'à l'activité nutritionnelle, en relation avec les variations de la demande en énergie. Pendant l'été et l'automne, l'énergie est utilisée pour la croissance somatique, tandis qu'en hiver elle est convertie dans le développement des gonades.

Key words. - Gadidae - *Trisopterus minutus* - MED - Adriatic Sea - Length-weight relationship - Gonadosomatic index.

The poor cod, *Trisopterus minutus* is a gadoid fish, which inhabits the Mediterranean and eastern Atlantic coast from Norway to the coast of Morocco (Svetovidov, 1986). It is common in the Adriatic Sea on the sandy-muddy bottoms between depths of 40 and 250 m (Jardas, 1996). It spawns in the winter-spring seasons (Jardas, 1996). In the Adriatic Sea, bottoms trawlers actively exploit poor cod (Gramitto, 1999). There are no reliable statistics on *Trisopterus minutus* landings in the eastern Adriatic but rough estimates of annual catch are around 40 tonnes (Jardas, 1996). In the Mediterranean, annual landings have fluctuated between 1191 to 3534 tonnes from 2003 to 2005 (FAO, 2007).

Different aspects of the biology and ecology of the poor cod were investigated in the Adriatic Sea. Giannetti and Gramitto (1988) analysed growth in the Italian waters of the Adriatic Sea. Šantić *et al*. (2009) described diet and seasonal variation in stomach contents. Grubišić (1988) and Jardas (1996) noted spawning period and values of gonadosomatic index (GSI). Froglia and Zoppini (1981), Tangerini and Arneri (1984) and Dulčić and Kraljević (1996) documented length-weight relationships (LWR). However, detailed seasonal changes in gonadosomatic index (GSI), and relationships with parameters of LWRs and condition factor have not yet been analysed for this species in the Adriatic Sea.

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Biology of poor cod was extensively investigated in Mediterranean Sea (Politou and Papaconstantinou, 1991; Biagi *et al*., 1992; Ragonese and Bianchini, 1998; Metin *et al*., 2006) and eastern Atlantic (Armstrong, 1982; Mattson, 1990).

Gonadosomatic index has largely been used as an indicator of changes during the gonadal development. In other hand, length-weight relationships have several applications, in the field of fish biology, physiology, ecology, and fisheries assessment. In biological studies, LWRs enable seasonal variations in fish growth to be followed as well as the calculation of condition indexes (Richter *et al*., 2000). Furthermore, LWRs are fundamental for the estimation of weight-at-age (Petrarkis and Stergiou, 1995), production and biomass of fish population (Anderson and Gutreuter, 1983). Finally, LWRs are useful for comparing fish population from different regions (Gonçalves *et al*., 1997).

This study presents the length-weight relationships as related to the gonadosomatic index and condition of poor cod. These data contribute to better knowledge of biology of this species in the eastern Adriatic Sea.

## MATERIAL AND METHODS

Samples of poor cod were collected in the eastern Adriatic Sea along the continental shelf, mostly at depths from 90 to 120 m (Fig. 1). Fish were sampled with commercial bottom-trawls (stretched cod-end mesh size of 22-24 mm).

Monthly samples were collected from January to December 2007 and a total of 1263 specimens (463 males and 800 females) were measured. Total length (TL) of all specimens was measured to the nearest 0.1 cm, and body weight to the nearest 0.1 g. Sex was assigned macroscopically. Gonads of all specimens were dissected and weighed to the nearest 0.001 g to calculate the gonadosomatic index (GSI = [Weight of gonads/Weight of fish] x 100). The relationship between weight and total length, $W = aL^b$, was converted into its logarithmic expression: $\log W = \log a + b \log L$. Parameter $b$ is the exponent of the arithmetic form of LWRs and the slope of regression line in the logarithmic form (Froese, 2006). The value of $b$ exponent indicates isometric and allometric growth. The parameters $a$ and $b$ were calculated by least-squares regression, as was the coefficient of determination ($R^2$). Statistical methods used for data analysis included the usual calculations of means and standard deviations. Significant difference of $b$ values from 3, which represents isometric growth, was tested with the $t$-test (Pauly, 1983). To test for possible significant differences between sexes we used analysis of covariance (ANCOVA).

Changes in condition were measured by indices of weight-length data. Condition factor (K) was estimated according to the Fulton equation: $K = (W/L^3) \times 100$.

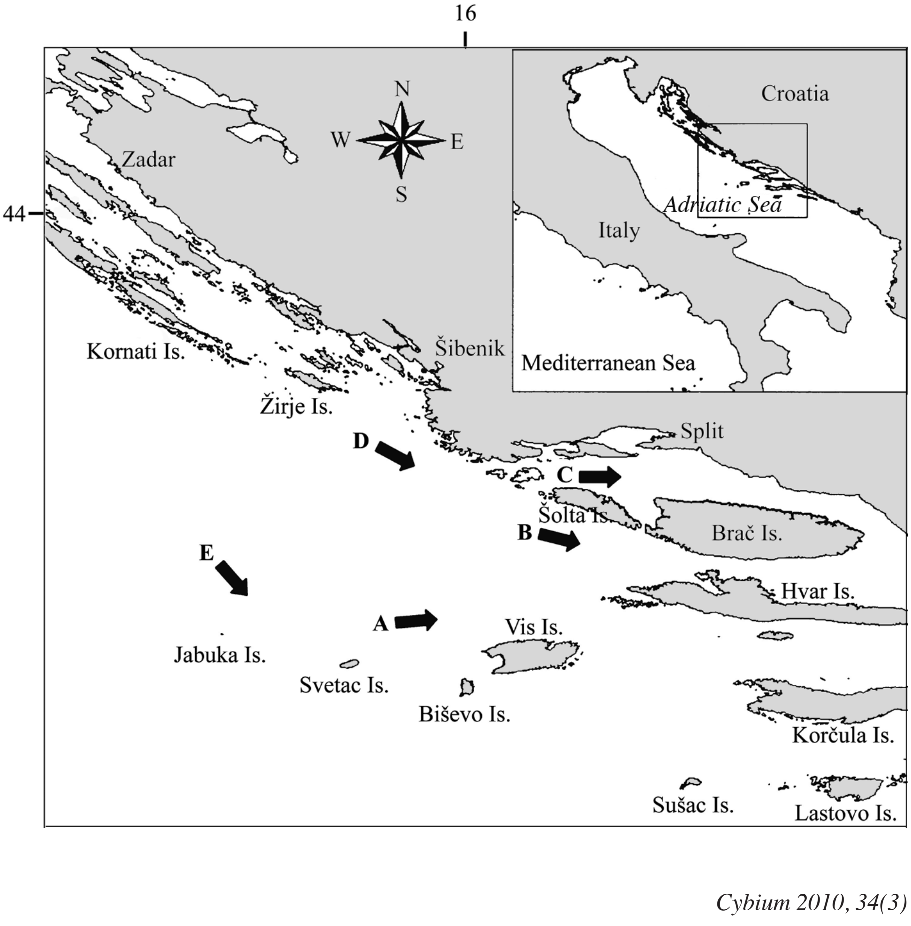

Figure 1. - Study area and sampling localities in the eastern Adriatic. A: Near islands Vis and Svetac; B: South of Maslenica; C: Split Channel; D: Blitvenica fishing area; E: Islands of Jabuka.

The correlation between values of *b* with GSI, and values of *b* with K over the course of year were tested by Pearson's correlation and was deemed significant when $p < 0.05$.

## RESULTS

Total lengths of males ranged from 8.9 to 21.5 cm, and weight from 7.0 to 120.1 g (Fig. 2A). Total lengths of females ranged from 10.3 to 25.5 cm, and weight from 10.0 to 194.2 g. (Fig. 2B). Number and length range of specimens, parameters *a* and *b* of the LWRs, standard error of *b*, coefficient of determination $R^2$ and *t*-values for each month are presented in table I. The sample size ranged from 113 individuals in February to 99 in July. The $R^2$ values ranged from 0.838 for females in March to 0.983 for males in May and all regressions were highly significant ($p < 0.001$).

The mean *b* values of poor cod ranged from 2.724 (S.E. = 0.210) for males in July to 3.381 (S.E. = 0.085) for females in February. The *b* values of males and females significantly increased in winter (February and March), while in summer (July and August) the values significantly decreased (*t*-test). Significant differences of *b* values between sexes were observed in February (ANCOVA: $F = 7.33$; $F_{0.01} = 6.85$; $p < 0.01$), March (ANCOVA: $F = 7.41$; $F_{0.01}= 6.85$; $p < 0.01$) and April (ANCOVA: $F = 8.01$; $F_{0.01}= 6.85$; $p < 0.01$) but, overall, there is no significant difference of *b* between sexes (ANCOVA-test).

Including all males (N = 463) and females (N = 800) collected during the year, values of *b* for males ($b = 2.930$; $t = 1.09$; $t_{0,01}$; $t_{\mathrm{crit}} = 2.58$), females ($b = 3.019$; $t = 1.36$; $t_{0.01}$; $t_{\mathrm{crit}} = 2.58$) and both sexes combined ($b = 2.981$; $t = 0.19$; $t_{0.01}$; $t_{\mathrm{crit}} = 2.58$) did not significantly differ from 3.

The monthly variation of GSI and values of *b* (for both sexes combined) are shown in figure 3A. The GSI reached maximum values in February and minimum values in September. Pearson's coefficient showed significant correlation between values of *b* and GSI ($r = 0.57$; $N = 1263$, $p < 0.05$). The monthly variations of parameter *b* and condition factor (K) are presented in figure 3B. Condition factor (K) of poor cod ranged from 0.94 (May and June) to 1.02 (August). Pearson's coefficient did not show a significant correlation between values of K and *b* ($r = -0.47$; $N = 1263$, $p > 0.05$). For both parameters studied, the Pearson's coefficient is calculated on the whole year.

## DISCUSSION

In the yearly sample, the *b* values for males, females and sexes combined showed that growth of poor cod was isometric i.e., proportional in length and weight. On the other hand,

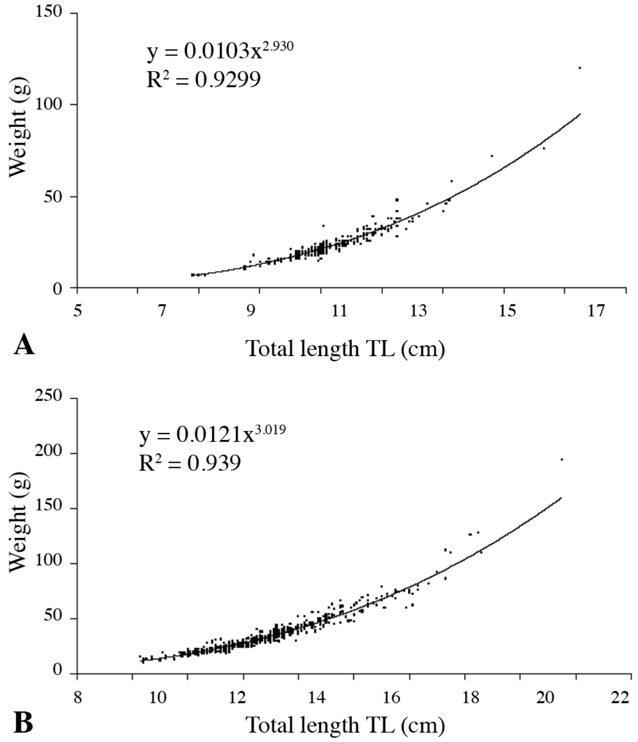

Figure 2. - Range of total length and weight of 463 males (**A**), and 800 females (**B**) of *Trisopterus minutus* collected in eastern Adriatic Sea during January-December 2007.

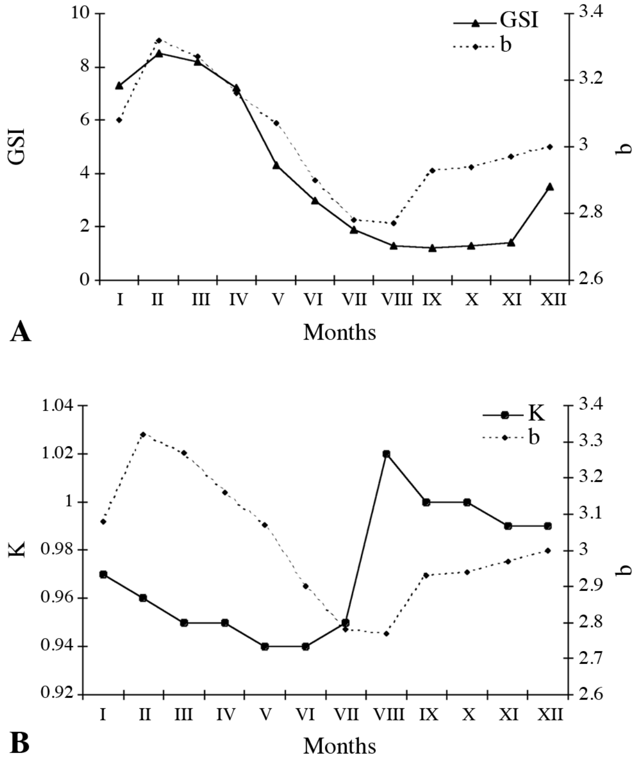

Figure 3. - Annual variations of *b* values with the gonadosomatic index (**A**) and with condition factor (**B**) in *Trisopterus minutus*

Table I. - Length-weight relationships ($W = aL^b$) of *Trisopterus minutus* in the eastern central Adriatic Sea during January-December 2007. Number of specimens (N), length range (cm TL), parameters *a* and *b* of the relationships ($W = aL^b$), standard error of *b* (S.E.), coefficient of correlation $R^2$, and *t*-values (I: isometry; P: positive allometry; N: negative allometry). * Significant differences (ANCOVA, $p < 0.01$) of *b* values between males (M) and females (F).

| Month | Sex | N | Length range (cm TL) | *a* | *b* | S.E (*b*) | $R^2$ | $\hat{t}$ | |
|---|---|---|---|---|---|---|---|---|---|
| January | M | 40 | 12.4-17.1 | 0.0087 | 3.021 | 0.169 | 0.909 | 0.27 | I |
| | F | 66 | 12.3-25.5 | 0.0082 | 3.100 | 0.059 | 0.970 | 1.26 | I |
| | Total | 106 | 12.3-25.5 | 0.0080 | 3.076 | 0.119 | 0.966 | 1.42 | I |
| February | M | 46 | 11.3-15.0 | 0.0062 | 3.181 | 0.163 | 0.929 | 3.02 | P |
| | F | 67 | 11.8-19.5 | 0.0050 | 3.381* | 0.085 | 0.950 | 3.22 | P |
| | Total | 113 | 11.3-19.5 | 0.0041 | 3.322 | 0.123 | 0.951 | 4.39 | P |
| March | M | 40 | 12.6-16.0 | 0.0016 | 3.179 | 0.267 | 0.841 | 2.90 | P |
| | F | 70 | 12.0-18.6 | 0.0030 | 3.370* | 0.153 | 0.838 | 3.20 | P |
| | Total | 110 | 12.0-18.6 | 0.0020 | 3.276 | 0.102 | 0.860 | 3.12 | P |
| April | M | 41 | 11.7-20.1 | 0.0134 | 3.030 | 0.145 | 0.919 | 1.61 | I |
| | F | 71 | 10.3-18.1 | 0.0080 | 3.219* | 0.089 | 0.948 | 2.79 | P |
| | Total | 112 | 10.3-20.1 | 0.0064 | 3.133 | 0.092 | 0.949 | 2.23 | I |
| May | M | 35 | 11.3-15.0 | 0.0067 | 2.899 | 0.072 | 0.985 | 2.06 | I |
| | F | 65 | 11.7-19.3 | 0.0201 | 3.104 | 0.086 | 0.936 | 2.32 | I |
| | Total | 100 | 11.3-19.3 | 0.0099 | 3.070 | 0.076 | 0.962 | 2.12 | I |
| June | M | 38 | 10.7-20.4 | 0.0109 | 2.892 | 0.291 | 0.850 | 1.43 | I |
| | F | 63 | 10.8-21.3 | 0.0131 | 2.957 | 0.109 | 0.906 | 1.93 | I |
| | Total | 101 | 10.7-21.3 | 0.0513 | 2.921 | 0.111 | 0.896 | 1.31 | I |
| July | M | 37 | 10.5-20.3 | 0.0087 | 2.724 | 0.210 | 0.950 | 3.64 | N |
| | F | 62 | 10.7-22.6 | 0.0213 | 2.788 | 0.087 | 0.931 | 3.23 | N |
| | Total | 99 | 10.5-22.6 | 0.0177 | 2.778 | 0.096 | 0.934 | 3.61 | N |
| August | M | 40 | 8.9-21.5 | 0.0117 | 2.740 | 0.140 | 0.955 | 3.21 | N |
| | F | 63 | 10.4-19.5 | 0.0266 | 2.802 | 0.921 | 0.927 | 2.90 | N |
| | Total | 103 | 8.9-21.5 | 0.0180 | 2.772 | 0.135 | 0.935 | 2.99 | N |
| September | M | 38 | 9.2-17.2 | 0.0070 | 2.907 | 0.126 | 0.945 | 1.74 | I |
| | F | 70 | 11.2-22.5 | 0.0101 | 2.984 | 0.079 | 0.954 | 0.22 | I |
| | Total | 108 | 9.2-22.6 | 0.0080 | 2.932 | 0.115 | 0.952 | 0.91 | I |
| October | M | 35 | 11.0-16.2 | 0.0163 | 2.930 | 0.216 | 0.912 | 0.77 | I |
| | F | 65 | 11.1-19.2 | 0.0096 | 2.976 | 0.095 | 0.925 | 0.98 | I |
| | Total | 100 | 11.0-19.2 | 0.0082 | 2.941 | 0.129 | 0.921 | 0.82 | I |
| November | M | 36 | 10.4-15.2 | 0.0181 | 2.994 | 0.236 | 0.877 | 0.19 | I |
| | F | 68 | 10.7-20.8 | 0.0173 | 3.030 | 0.095 | 0.915 | 0.28 | I |
| | Total | 104 | 10.4-20.8 | 0.0146 | 2.975 | 0.102 | 0.909 | 0.20 | I |
| December | M | 37 | 11.2-14.9 | 0.0199 | 2.963 | 0.149 | 0.892 | 0.40 | I |
| | F | 70 | 11.4-18.1 | 0.0098 | 3.005 | 0.129 | 0.909 | 0.12 | I |
| | Total | 107 | 11.2-18.1 | 0.0096 | 3.011 | 0.104 | 0.900 | 0.34 | I |
| All months | M | 463 | 8.9-21.5 | 0.0010 | 2.930 | 0.140 | 0.929 | 1.73 | I |
| | F | 800 | 10.3-22.5 | 0.0012 | 3.019 | 0.112 | 0.939 | 2.44 | I |
| | Total | 1263 | 8.9-22.5 | 0.0011 | 2.981 | 0.218 | 0.904 | 0.85 | I |

Froglia and Zoppini (1981), Tangerini and Arneri (1984) and Dulčić and Kraljević (1996) noted positively allometric growth of poor cod in the Adriatic Sea. The observed difference in Adriatic population could be due to the period of capture, stage of gonad maturity, length of fish and sample size. For instance, in the work of Froglia and Zoppini (1981), poor cod were collected during the spawning period (winter), when gonads were massive, which increased growth exponent (*b*). Tangerini and Arneri (1984) sampled fish only in May, when parameter of *b* has relatively high values. Positively allometric growth reported by Dulčić and Kraljević (1996) could be explained by small samples size dominated by larger individuals. Values of *b* exponent reported in the eastern coast of Greek waters and northern Aegean Sea (Papaconstantinou *et al.*, 1989; Politou and Papaconstantinou, 1991; Papaconstantinou *et al.*, 1993) also significantly differed from our result. These differences probably reflect the growth variations due to environmental factors such as temperature and salinity in the different areas of investigation. For instance, the average annual surface sea temperature of the northern Aegean Sea is 15-17°C with an average salinity of 33 ppt (Poulos *et al.*, 1997), whereas the average annual surface temperature in the central Adriatic ranges between 14 and 25ºC with salinity of 38.3 ppt (Zore-Armanda *et al.*, 1991). Water temperature is known to be related to rates of primary biological production and consequently the composition and abundance of plankton influences their availability for fish growth (Colerbook, 1982; Weatherley and Gill, 1987). In addition, possible genetic differences between population from different area as well as gear selectivity, level of exploitation, variations in fish shape and stomach fullness can also affect the value of *b* (Shepherd and Grimes, 1983; Politou and Papaconstantinou, 1991; Mommsen, 1998).

Estimate of *b* showed seasonal variations. Positive allometric growth was noted in winter (February and March), while in summer (July and August) negative allometric growth was observed. In other months fish grew isometrically. The seasonal variation of *b* values was probably related to the reproductive cycle of this species as indicated by significant correlation of gonadosomatic index and *b* values observed throughout the year. Macroscopic investigation of gonads and annual curve of gonadosomatic index indicate prespawning period from November to December, spawning period from January to May with intensity during February and March and post-spawning period from July to October. Maximum *b* values in both sexes were observed during the period when the gonadosomatic index showed also pronounced peak (February and March), due to fully developed and massive the testis and ovaries. During the winter with further gonad development the fish abdomen became thicker which results in positive allometric growth (Metin *et al.*, 2006). On the contrary, gonadal regression during the spawning stage decreased GSI and probably influenced *b* values in males and females. After the spawning period gonads were string shaped. Conversion of the gonad tissue, with high water content, into fat will decrease the body weight (Viette *et al.*, 1997). This process can explain the negative allometry from July to August in both sexes.

The condition factor based on the LWR is an indicator of the changes in food energy and therefore an indicator of the general fish condition. Seasonal variation in poor cod condition suggested possible relation to gonadal changes. Condition factor was constant during prespawning period, decreased in the period of spawning and was lowest in June and July, immediately after spawning. Drop in condition factor after spawning suggested that cost of reproduction in this fish was very high (Politou and Papaconstantinou, 1991). The poor cod is a serial spawner with a prolonged spawning period (Ragonese and Bianchini, 1998) that probably caused loss of energy stored in muscle and mesenteric fat. The reproductive strategy of this species tends to maximize reproductive potential (Politou and Papaconstantinou, 1991). The strategy is a combination of extended spawning season, early maturation, high fecundity and extensive migration across the continental shelf during spawning (Politou and Papaconstantinou, 1991). These statements probably explain decreased condition factor after long spawning period. Expended energy is replaced by intensified feeding of this species in the period after spawning, throughout summer (Šantić *et al.*, 2009). Intensified feeding during the summer is supported by higher water temperatures and increased abundance of prey (Šantić *et al.*, 2009). Specimens were in best condition in August when gonads are in resting phase. Probably, increased feeding in post-spawning period and recovery phase of gonads can explain the highest condition of fish obtained in August. Politou and Papaconstantinou (1991) also reported that condition of poor cod decreases in spring and was lowest immediately after spawning period as well as that it tends to increase in autumn, during post-spawning period. Variation of values of GSI, *b* and condition factor possibly explained energy expenditure for reproduction process and somatic growth. During the summer-autumn seasons when GSI and *b* were low and condition highest, energy is strictly spent for somatic growth. When GSI started to increase in December the condition factor and values of *b* started to change and during the winter energy was converted in gonadal development. Energy accumulated through the summer when feeding activity is more pronounced, is spent for gametogenesis and reproductive activity through winter (Šantić *et al.*, 2009).

In conclusion, in the eastern Adriatic Sea, the poor cod grows isometrically. The allometric parameter *b* varies throughout the year. Positive allometric growth was noted during the winter when the gonadosomatic index showed a pronounced peak, while in summer negative allometric growth was observed. In other months fish grew isometrically. Condition factor was lowest immediately after spawning period and highest at gonad resting phase and intensive summer feeding. Seasonal variations of LWRs and condition factor of poor cod were connected with the gonadal changes, feeding activity and energy distribution. During the summer-autumn season, the energy is spent for somatic growth while in winter it is converted in gonad development. The presented data extend our knowledge of the biology of this species and provide basic information for the development of multispecies assessment models for this area.

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